EXHIBIT 57

Health Consultation

Potential Cumulative Health Effects Associated with Eating Spokane River Fish
Spokane, Spokane County, Washington

August 5, 2011

Prepared by

The Washington State Department of Health
Under a Cooperative Agreement with the
Agency for Toxic Substances and Disease Registry

Washington State Department of Health
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Foreword

The Washington State Department of Health (DOH) has prepared this health consultation in accordance with methodologies and guidelines developed by the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR is part of the U.S. Department of Health and Human Services and is the principal federal public health agency responsible for health issues related to hazardous waste sites and releases.

The purpose of this health consultation is to identify and prevent harmful human health effects resulting from exposure to hazardous substances in the environment. Health consultations focus on specific health issues so that DOH can respond to requests from concerned residents or agencies for health information on hazardous substances. DOH evaluates sampling data collected from a hazardous waste site, determines whether exposures have occurred or could occur, reports any potential harmful effects, and recommends actions to protect public health. The findings in this report are relevant to conditions at the site during the time of this health consultation and should not necessarily be relied upon if site conditions or land use changes in the future.

This report was supported by funds from a cooperative agreement with ATSDR. However, it has not been reviewed and cleared by ATSDR.

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For people with disabilities, this document is available on request in other formats. To submit a request, please call 1-800-525-0127 (TTY/TDD call 711).

For more information about ATSDR, contact the ATSDR Information Center at 1-888-422-8737 or visit the agency's Web site: www.atsdr.cdc.gov/.

Glossary

Agency for Toxic Substances and Disease Registry (ATSDR)	The principal federal public health agency involved with hazardous waste issues, responsible for preventing or reducing the harmful effects of exposure to hazardous substances on human health and quality of life. ATSDR is part of the U.S. Department of Health and Human Services.
Cancer Risk	A theoretical risk for developing cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.
Cancer Risk Evaluation Guide (CREG)	The concentration of a chemical in air, soil, or water that is expected to cause no more than one excess cancer in a million persons exposed over a lifetime. The CREG is a *comparison value* used to select contaminants of potential health concern and is based on the *cancer slope factor* (CSF).
Cancer Slope Factor	A number assigned to a cancer-causing chemical that is used to estimate its ability to cause cancer in humans.
Carcinogen	Any substance that causes cancer.
Comparison Value (CV)	Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.
Contaminant	A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.
Dose (for chemicals that are not radioactive)	The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An “exposure dose” is how much of a substance is encountered in the environment. An “absorbed dose” is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.
Environmental Media Evaluation Guide (EMEG)	A concentration in air, soil, or water below which adverse non-cancer health effects are not expected to occur. The EMEG is a *comparison value* used to select contaminants of potential health concern and is based on ATSDR’s *minimal risk level* (MRL).

Environmental Protection Agency (EPA)	United States Environmental Protection Agency.
Exposure	Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [**acute exposure**], of intermediate duration, or long-term [**chronic exposure**].
Ingestion	The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see **route of exposure**].
Ingestion Rate (IR)	The amount of an environmental medium that could be ingested typically on a daily basis. Units for IR are usually liter/day for water and mg/day for soil.
Inorganic	Compounds composed of mineral materials including elemental salts and metals such as iron, aluminum, mercury, and zinc.
Lowest Observed Adverse Effect Level (LOAEL)	The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.
Media	Soil, water, air, plants, animals, or any other part of the environment that can contain contaminants.
Minimal Risk Level (MRL)	An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see **oral reference dose**].
No Observed Adverse Effect Level (NOAEL)	The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.
Oral Reference Dose (RfD)	An amount of chemical ingested into the body (i.e., dose) below which health effects are not expected. RfDs are published by EPA.
Organic	Compounds composed of carbon, including materials such as solvents, oils, and pesticides that are not easily dissolved in water.

Parts per billion (ppb)/Parts per million (ppm)	Units commonly used to express low concentrations of contaminants. For example, 1 ounce of trichloroethylene (TCE) in 1 million ounces of water is 1 ppm. 1 ounce of TCE in 1 billion ounces of water is 1 ppb. If one drop of TCE is mixed in a competition size swimming pool, the water will contain about 1 ppb of TCE.
Reference Dose Media Evaluation Guide (RMEG)	A concentration in air, soil, or water below which adverse non-cancer health effects are not expected to occur. The RMEG is a *comparison value* used to select contaminants of potential health concern and is based on EPA's oral reference dose (RfD).
Route of exposure	The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].

Summary

The Washington State Department of Health (DOH) conducted this health consultation to determine the potential cumulative health effects associated with eating contaminated fish caught in three sections of the Spokane River:

- Long Lake (also known as Lake Spokane);
- Nine Mile Dam to Upriver Dam, including Mission Park and Nine Mile reaches; and
- Upriver Dam to Idaho border, including Plante's Ferry Park and the Idaho stateline reaches.

This work was done in response to a request from the Center for Justice and to ensure that the community has the best information possible to safeguard its health.

DOH reached three important conclusions in this health consultation:

Conclusion 1

DOH concludes that eating both fillet and whole fish containing polychlorinated biphenyls (PCBs) from the Spokane River for about 30 years could harm recreational angler's health due to cancer health effects. This is *a public health hazard*. People who eat only whole fish will be at higher risk than those who eat fillets because whole fish contains higher levels of PCB contaminants than fillets.

Basis for decision:

Based on exposure assumptions and calculations (recreational anglers eating whole fish 30% of the time and fillet 70% of the time, 365 days per year at a rate of 42 grams per day), the PCB theoretical cancer risk exceeds 1 excess cancer in 10,000 people exposed. This risk level is considered to have a significant impact on lifetime cancer risk.

Conclusion 2

DOH concludes that eating fish for more than a year at some Spokane River locations where fish contain high levels of PCBs and polybrominated diphenyl ethers (PBDEs) is likely to harm people's health due to non-cancer health effects. This is *a public health hazard*.

Basis for decision:

Based on exposure assumptions and calculations (people eating whole fish 30% of the time and fillets 70% of the time, 365 days per year at a rate of 17.5 grams per day for general population and 42 grams per day for recreational anglers), PCBs and PBDEs in

Spokane River fish are at levels of health concern. The hazard index is greater than individual hazard quotients for either PCBs or PBDEs, and the dose of one or more of the individual chemicals are within one order of magnitude of its respective lowest-observed-adverse effect level (LOAEL) for PCBs (see total sum, Table 3). In general, potential health risks are much lower when consumers eat only fish fillets (100% of the time) compared to whole fish.

Conclusion 3

DOH concludes that eating Spokane River fish could harm people's health from the combination of chemicals (i.e., PCBs, PBDEs, and metals) with similar target organs toxicity. This is a *public health hazard*.

Basis for decision:

While evidence is lacking that PBDEs interactively enhance the toxicity of PCBs, DOH is taking a precautionary approach by assuming joint additivity. Since the toxicity is likely no less than that predicted for single chemical toxicity, DOH chose to err on the side of concern/prevention.

Next Steps:

- Since there are no direct data available to characterize dose-response relationships from exposures to PCB and PBDE chemical mixtures, DOH will continue to monitor new research to address this data gap.

- The fish advisory for the Spokane River should remain in place based on the 2007 health consultation and this evaluation on the cumulative effects of PCBs and PBDEs. For more information, visit the DOH fish consumption website: www.doh.wa.gov/fish.

    - DOH recommends against any consumption of fish between the Idaho border and Upriver Dam. For the reach between Upriver Dam and Nine Mile Dam, DOH advises against eating more than one meal per month of any species. Additionally, DOH advises consumers not to eat large scale sucker at this location. For the reach between Nine Mile Dam and Long Lake (Upper and Lower Long Lake), DOH advises no more than one meal per month for large scale sucker and brown trout, and no more than one meal per week for mountain whitefish.

        - *There is a statewide freshwater bass and northern pikeminnow advisory due to mercury. Limit largemouth and smallmouth bass to two meals per month; do not consume northern pikeminnow. Check for fish advisories at* www.doh.wa.gov/fish.

  - In order to reduce exposure to PCBs and PBDEs from the consumption of fish, DOH recommends eating fillets instead of whole fish, removing the skin, and cleaning all fish. DOH also recommends that the fish be prepared by grilling, broiling, or baking so the fat can drip off and not to use fat in gravy or sauces.

- DOH recommends continued monitoring for PBDEs and PCBs in the Spokane River.

- Future updates of the Spokane River fish advisory should be based on long-term fish tissue monitoring trends.

- DOH will provide copies of this health consultation to the Center for Justice, Environmental Stewardship Concepts, Washington State Department of Ecology, Spokane Regional Health District, and other concerned parties.

- DOH may develop additional educational materials on fish consumption for the Spokane River.

For More Information:

Please feel free to contact Barbara Trejo at 360-236-3373 or toll free at 1-877-485-7316 if you have any questions about this health consultation.

Introduction

The Washington State Department of Health (DOH) conducted this health consultation in response to a March 30, 2009, request from the Center for Justice. The Center for Justice was concerned the DOH *Health Consultation, Evaluation of PCBs, PBDEs and Selected Metals in the Spokane River, Including Long Lake - Spokane, Washington*, August 28, 2007, did not address the cumulative effects of contaminants of concern via fish consumption. The basis for the Center for Justice concern was provided in a March 24, 2009, paper prepared by Environmental Stewardship Concepts (Dr. Peter deFur).[1]

Background

DOH evaluated the potential adverse health effects associated with eating contaminated fish from the Spokane River on a chemical-by-chemical basis during its 2007 health consultation.[a] PCBs, PBDEs[b], and lead[c] were identified as the contaminants of concern. Cancer and non-cancer hazards associated with exposure to these individual chemicals via fish consumption were evaluated.[5] The health consultation findings led to an update of the Spokane River fish advisory.

DOH's initial response to the Center for Justice's concern about the 2007 health consultation occurred in May 2009. In that response, DOH pointed out the complexity and uncertainties regarding evaluating multiple chemical exposures from consumption of contaminated fish from the Spokane River. However, DOH did agree to evaluate the cumulative risk for immune system and developmental effects for the general population and recreational fishermen based on multiple chemicals using 2005 fish data for three sections of the Spokane River:

- Long Lake (also known as Lake Spokane);
- Nine Mile Dam to Upriver Dam, including Mission Park and Nine Mile reaches; and
- Upriver Dam to Idaho border, including Plante's Ferry and the Idaho stateline reaches.

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[a] The 2007 health consultation report, which led to an update of the Spokane River fish advisory, is available online at http://www.doh.wa.gov/consults.
[b] A list of the main PBDE congeners found in fillet and whole fish from the Spokane River is provided in Appendix D. The primary PBDEs detected were PBDE-47, -99, and -100, which comprised approximately 90% of the total.
[c] Lead was mostly found in the whole fish of large scale sucker and bridgelip sucker. The highest concentration of lead was found at the Idaho stateline location. At this location, the fish advisory warns against any consumption of fish, only catch and release.

Results

Table 1 presents the mean concentration for total PBDEs and total PCBs found in Spokane River fish (fillet and whole fish[d]) in 2005 compared to subsistence comparison values.[4] Appendix C presents a summary of the maximum levels of metals in Spokane River fish compared to subsistence consumption comparison values.

Contaminant Screening

Fillet and whole body sample contaminant data were screened using conservative comparison values protective of subsistence fish consumers, (Table 1). DOH derived these comparison values using high-end consumption rates presented in EPA's fish advisory guidance documents (Appendix A).

Table 1 shows the mean concentration of PCBs and PBDEs measured in Spokane River fish compared to health-based subsistence consumer comparison values. Appendix C, Table C1 shows the maximum concentrations of arsenic, cadmium, lead, and zinc compared to subsistence comparison values. Only lead, PCBs, and PBDEs had levels that exceeded EPA's subsistence comparison values. Therefore, lead, total PCBs, and total PBDEs were evaluated further as contaminants of concern (COCs). The fact that a contaminant exceeds its health comparison value does not mean that a public health hazard exists, but rather signifies the need to consider the chemical further.

Discussion

For many individual chemicals, information is available on how the chemical might produce health effects in animals; some information may also be available on the impacts to human health. However, it is much more difficult to assess exposure to multiple chemicals. Due to the large number of chemicals in the environment, it is impossible to measure all of the possible interactions between these chemicals. The potential exists for these chemicals to interact in the body and increase or decrease the potential for adverse health effects. Individual cancer risk estimates can be added since they are measures of probability. However, when estimating non-cancer risk, similarities must exist between the chemicals if the doses are to be added. Groups of chemicals that have similar toxic effects can be added, such as volatile organic compounds (VOCs), which cause liver toxicity. Polycyclic aromatic hydrocarbons (PAHs) are another group of compounds that can be assessed as one combined dose based on similarities in chemical structure and metabolites.

[d] Whole body fish were prepared by methods described by EPA and Washington State toxics Monitoring Program for screening level assessment of contaminants in fish tissue.[2, 3] Bottom fish were sectioned and homogenized whole (guts and scales on) in a commercial meat grinder.

Table 1. Mean concentrations of total PCBs and PBDEs in Spokane River fish (fillet and whole) compared to subsistence consumption screening values

Contaminant	Mean concentration (mg/kg) wet weight	Subsistence Comparison Value (mg/kg)	RfD (mg/kg/day)	Contaminant of concern
Total PBDEs (fillet)	**0.4236** [a]	0.049 [e]	0.0001*	**Yes**
Total PBDEs (whole) †	**2.2** [b]			
Total PCBs (fillet)	**0.1617** [c]	0.00983 [1]	0.00002	**Yes**
Total PCBs (whole) †	**0.2838** [d]			

NA – Not available
BOLD - Values exceed comparison value.
[a] – **Fillet** – Total PBDE concentration calculated based on consumption of rainbow trout (fillet) (70%), plus mountain white fish (fillet) (15%), and brown trout (fillet) (15%) using the maximum value of the mean concentration for each species.
[b] – **Whole** – Total PBDE concentration calculated based on consumption of rainbow trout (whole body) (70%), large scale sucker (whole body) (15%), and mountain whitefish (whole body) (15%) using the maximum value of the mean concentration for each species.
[c] – **Fillet** – Total PCB concentration calculated based on consumption of rainbow trout (fillet) (70%), plus mountain white fish (fillet) (15%) and brown trout (fillet) (15%) using the maximum value of the mean concentration for each species.
[d] – **Whole** – Total PCB concentration calculated based on consumption of large scale sucker (whole body) (15%) and bridgelip sucker (whole body) (15%) using the maximum value of the mean concentration for each species.
PBDE – Polybrominated diphenyl ether
PCB – Polychlorinated biphenyl
* Reference dose (RfD) - used EPA's Brominated Diphenyl Ether (BDE-47). Appendix B lists EPA's reference dose values for PBDEs
† Whole body fish represents the results of whole fish homogenized with guts and scales on.
[e]- See Appendix A for calculation of screening value. This value was derived based on the RfD for BDE-47, a consumption rate of 142 grams/day, and an average adult body weight of 70 kilograms (kg)
[1] - U.S. Environmental Protection Agency. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories - Volume 1, Fish Sampling and Analysis, Third Edition. 2000. EPA-823-B-00-007.

Chemical mixtures

DOH's approach for the assessment of exposure to chemical mixtures includes reviewing available chemical mixtures studies for non-cancer and cancer health effects. To conduct exposure-based assessments of possible non-cancer or cancer health hazards from oral exposures to mixtures of total PBDEs and total PCBs, the Agency for Toxic Substances and Disease Registry (ATSDR) recommends conducting a component-based approach.[6] This is because there is no direct approach to characterize health hazards and low dose-response relationships from exposure to mixtures of these two chemicals. No studies were located that examined health effects in humans or animals exposed to mixtures exclusively containing PCBs and PBDEs. In addition, physiological-based

pharmacokinetic/pharmacodynamic (PBPK/PD) models have not yet been developed that would predict appropriate target doses of the components.

Assumptions for Spokane River fish

An exposure scenario was assumed for the general population and recreational anglers who consume fish (both fillet and whole body fish) from the Spokane River. This scenario assumed that rainbow trout is consumed 70% of the time, while other species of fish (e.g., large scale sucker, bridgelip sucker, smallmouth bass, brown trout, and mountain whitefish) found in the Spokane River are consumed 30% of the time (see Table 1 and Appendix B, Table B1). Rainbow trout, brown trout, and smallmouth bass are targeted fish species for human consumption from the Spokane River site. However, brown trout are not as abundant in the Spokane River and there is a statewide freshwater bass advisory due to mercury[e]. While some people eat whitefish, large scale suckers, and bridgelip suckers, they are not a targeted fish species. Therefore, the assumption that 70% of fish that people may consume is rainbow trout is not unreasonable; in some cases it could be as much as 100%.

DOH considers that this approach is very protective for consumers (i.e., general population and recreational anglers) that may eat whole fish and fillets from the Spokane River. Appendix B, Table B1 lists exposure assumptions and calculations used for Spokane River fish.

Evaluating non-cancer hazards

As mentioned earlier, exposure assumptions for estimating contaminant doses from fish consumption are found in Appendix B, Table B1. A dose is estimated for each contaminant of concern (COC) in order to evaluate the potential for non-cancer adverse health effects that may result from exposure to contaminated fish. These doses are calculated for situations (scenarios) in which a person might be exposed. The estimated dose for each contaminant under each scenario is then compared to ATSDR Minimal Risk Levels (MRLs). MRLs are an estimate of the daily human exposure to a substance that is likely to be without appreciable risk of adverse health effects during a specified duration of exposure. MRLs are based only on non-carcinogenic effects. In the absence of MRLs, DOH uses the EPA's oral reference doses (RfDs). RfDs are doses below which non-cancer adverse health effects are not expected to occur ("safe" doses). MRLs and/or RfDs are derived from toxic effect levels obtained from human population and laboratory animal studies.

Because of data uncertainty, the toxic effect level is divided by uncertainty factors to produce the lower and more protective MRL. If a dose exceeds the MRL, this indicates only the potential for adverse health effects. The magnitude of this potential can be inferred from the degree to which this value is exceeded. If the estimated exposure dose is only slightly above the MRL, then that dose will fall well below the observed toxic

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[e] This advisory limits largemouth and smallmouth bass to two meals per month. Check for fish advisories at www.doh.wa.gov/fish.

effect level. The higher the estimated dose is above the MRL, the closer it will be to the actual observed toxic effect level. This comparison is called a hazard quotient (HQ). See Appendix B for the hazard quotient equation. The toxic effect levels can be either the lowest-observed adverse effect level (LOAEL) or a no-observed adverse effect level (NOAEL). In human or animal studies, the LOAEL is the lowest dose at which an adverse health effect is seen, while the NOAEL is the highest dose that does not result in any adverse health effects. If the hazard quotient is above one, DOH evaluates the contaminant further and compares the estimated dose to the LOAEL and/or NOAEL.

ATSDR's approach for evaluating non-cancer health effects recommends calculating the hazard quotient (HQ) for each chemical in the mixture:

- If one individual chemical HQ exceeds 1.0, the individual chemical needs further evaluation.
- If more than one chemical HQ exceeds 0.1, the mixtures need to be evaluated for interactive effects.
- If no more than one chemical HQ exceeds 0.1, no significant interactive effects are expected and no further evaluation is needed.

Appendix B, Tables B3 and B4 show non-cancer hazards associated with exposure to contaminants of concern in Spokane River fish. Since hazard quotients exceed 1.0, PCBs and PBDEs will be evaluated further as contaminants of concern.

Non-cancer health effects

Relatively few studies have assessed toxic interactions of non-carcinogenic chemicals in low dose ranges. The studies that exist suggest that no adverse health effects occur from mixtures in dosed animals when the components of that mixture are present at levels below their respective NOAEL(i.e., at concentrations that would have produced no adverse effects in animals treated with those separate chemical components). In two of these experiments[7, 8] , all of the component chemicals affected the same target organ, but through different mechanisms. In two others[9, 10] , the chemicals affected different target organs and exhibited different modes of action, as do most chemicals in typical environmental mixtures. Subsequent experiments have shown similar results.[11, 12, 13]

DOH calculated the cumulative effects of PCBs and PBDEs for developmental response. There is no scientific evidence that the two components of the mixture can act (i.e., have an effect) in an interactive way on the developing nervous system (i.e., toxicity pathways are unknown). Information on possible health impacts of PBDEs comes primarily from animal toxicity studies and there is no information regarding low level exposure to PBDEs on humans. The most sensitive toxic effect associated with some forms of PBDEs, such as penta-PBDE congeners, appears to be developmental neurotoxicity, although penta-PBDE may also impact thyroid and other hormone systems. Human health risks may be associated with PBDE exposure but toxicity mechanisms and levels that may result in harm are not clearly understood. On the other hand, it's known that PCBs can cause adverse health effects in humans affecting reproduction, developmental,

and endocrine function. Other toxic responses to PCBs include dermal toxicity, immunotoxicity, and carcinogenicity.

To calculate the hazard index of the two components of the mixture for non-cancer health effects, the following variables were considered: 1) joint additive actions of the components on developmental toxicity was assumed; 2) the mean concentration of PCBs and PBDEs found in fish (whole body and/or fillet) were used in the equation; 3) intakes were divided by the MRL and or RfD; and 4) the resulting hazard quotients were summed to arrive at a hazard index (Appendix B, Tables B3 and B4). Since there is no information on the carcinogenicity of PBDEs regarding cancer effects in humans (i.e., there is no cancer slope factor for PBDEs), the cancer endpoint is unknown. There is inadequate information to assess the carcinogenic potential of BDE-99 (penta), BDE-47 (tetra), and BDE-153 (hexa)[14, 15] in humans. However, the weight of evidence for BDE-209 (deca) is characterized as "suggestive evidence of carcinogenic potential" in rats and mice.

Although no human studies are available, two chronic exposure studies using rodents provide suggestive evidence of decaBDE-induced carcinogenicity. The weight of evidence of human carcinogenicity to decaBDE is based on: 1) no studies of cancer in humans exposed to decaBDE; 2) a significantly increased incidence of neoplastic nodules in the liver of low- and high-dose male rats and high-dose female rats; 3) a significantly increased incidence of hepatocellular adenoma or carcinoma (or combined) in male mice at low dose and marginally increased incidence at high dose; 4) a insignificantly increased incidence of hepatocellular adenoma or carcinoma (combined) in female mice; 5) a slight (but statistically not significant) increase in incidence of thyroid gland adenomas or carcinomas (or combined) in both male and female mice; 6) a significantly increased incidence in male mice of follicular cell hyperplasia, considered by many as a precursor to thyroid tumors; and 7) an apparent absence of genotoxic potential. All of the data supporting carcinogenicity were obtained from chronic studies in rats and mice.[16]

Since there is no information on the evidence of carcinogenicity for humans, EPA's recommendation is to not attempt a dose-response assessment, as the nature of the data generally would not support one. However, when the evidence includes a well-conducted study, quantitative analyses may be useful for some purposes (e.g., providing a sense of the magnitude and uncertainty of potential risks, ranking potential hazards, or setting research priorities). In each case, the rationale for the quantitative analysis is explained, considering the uncertainty in the data and the suggestive nature of the weight of evidence. These analyses generally would not be considered U.S. EPA's consensus estimates.

The pertinent oral minimal risk levels (MRLs) and target-organ toxicity doses (TTDs) for endpoints of concern (child development and impacts on the immune system) for each component of the mixture are listed in Table 2.

For the PCBs and PBDEs detected in Spokane River fish, the average concentrations detected for both fillet and whole body samples would result in ingestion doses that

exceed the health guideline for each chemical (Appendix B, Tables B3 and B4). Exposure to the mixture might constitute a hazard if the hazard index (HI) for PCBs and PBDE exceeds one. When the HI for PCBs and PBDE exceeds one, further toxicological evaluation is needed to determine if harmful effects might be possible.

Table 2. Minimal risk levels and target-organ toxicity doses (TTD)[17] for repeated oral exposures to chemicals of concern.

Endpoint	PCBs	PBDEs
	mg/kg/day	
Hepatic	1×10^{-4} [a]	NA
Endocrine	1×10^{-4} [b]	NA
Immunological †	2×10^{-5} (chronic MRL)	NA
Neurological	3×10^{-5} (intermediate MRL)	1×10^{-4} [d]
Reproductive	2×10^{-5} [c]	NA
Developmental †	3×10^{-5} (intermediate MRL)	1×10^{-4} [e]

† Assuming endpoints are similar for immunological and developmental toxicity. It is unknown whether exposure to mixtures containing PCBs and/or PBDEs will affect the same target organ through different and/or similar modes of action. PCBs and/or PBDEs can target a wide range of overlapping health endpoints, and the critical effects can vary among these chemicals depending on the component and the duration of exposure.

[a] – This number is derived by applying an uncertainty factor of 300 (10 for use of a LOAEL, 3 for extrapolation from monkeys to humans, and 10 for human variability) to the LOAEL of 0.04 mg/kg/day for decreased serum cholesterol in Rhesus monkeys (Arnold et al. 1993a, 1993b) yields a $TTD_{HEPATIC}$ of 0.1 ug/kg/day (1×10^{-4} mg/kg/day) for PCB mixtures.

[b] – This value is derived by dividing the rat LOAEL of 0.09 mg/kg/day for decreased serum thyroid hormone levels produced by intermediate-duration exposure (Byrne et al. 1987) by an uncertainty factor of 1,000 (10 for the use of a LOAEL, 10 for extrapolating from rats to humans, and 10 for human variability) yields a $TTD_{ENDOCRINE}$ of 0.1 ug/kg/day (1×10^{-4} mg/kg/day). This value is expected to be protective of chronic-duration exposure because of the large uncertainty factor.

[c] – This number is based on a chronic serious LOAEL for reproductive toxicity (reduced conception rate) in monkeys of 0.02 mg/kg/day, which yields a $TDD_{Reproductive}$ of 0.00002 mg/kg/day (2×10^{-5} mg/kg/day) in humans (1000 for extrapolating from monkeys to humans).

[d]- This value corresponds to EPA's oral RfD for penta bromodiphenyl ether (BDE-99) and tetra bromodiphenyl ether (BDE-47) neurobehavioral effects.

[e]- This value corresponds to the reference dose for the lower brominated (tetra and penta) PBDEs.

NA – Not available

General population estimated dose

A child (0 to 6 years old) consuming 7.0 grams per day of fish (fillet) that contains both total PCBs and total PBDEs from the Spokane River would result in an average exposure dose of 0.00019 mg/kg/day. Similarly, a child (0 to 6 years old) consuming 7.0 grams of whole fish that contains both total PCBs and total PBDEs from the Spokane River would result in an average exposure dose of 0.00071 mg/kg/day (see Appendix B, Table B3). The chronic LOAEL for PCBs is 0.005 mg/kg/day, and the chronic serious (i.e., the next highest dose level) LOAEL for reproductive toxicity is 0.02 mg/kg/day.

The PCBs LOAEL of 0.005 mg/kg/day is based on clinical observations of monkeys exposed to 0.005 – 0.08 mg/kg/day of Aroclor 1254 during the first 37 months of the study. Health effects of decreased antibody response and eyelid and toe/fingernail changes were observed in female Rhesus monkeys chronically exposed to these levels.[18] The LOAEL for pentaBDE-99 for neurobehavioral effects is 0.29 mg/kg/day (this LOAEL is equal to the EPA's 95% lower bound on the benchmark dose – BMDL). This value is derived from mice and rat animal studies.

The highest estimated child dose (0 to 6 years old) *(worst case scenario)* based on whole fish for PCBs and PBDEs is 0.00071 mg/kg/day (Table 3 and Appendix B, Table B3), which exceeds the MRL of 0.00001 mg/kg/day for PCBs, and also exceeds the MRL of 0.0001 mg/kg/day for PBDEs. However, the estimated dose is 7 times below the LOAEL of 0.005 mg/kg/day for PCBs for immunological, dermal, developmental, and neurological effects; and 409 times below the LOAEL of 0.29 mg/kg/day for PBDEs. As mentioned earlier, the LOAEL for PCBs is based on clinical observations of monkey studies with durations of 5 weeks to 1 or 2 years. The same dose is 28 times below the chronic serious LOAEL for PCBs of 0.02 mg/kg/day for reproductive toxicity.

The highest estimated adult dose based on whole fish for PCBs and PBDEs is 0.00019 mg/kg/day (Table 3 and Appendix B, Table B3), which exceeds the MRL of 0.00001 mg/kg/day for PCBs, and also exceeds the MRL of 0.0001 mg/kg/day for PBDEs. However, the estimated dose is 26 times below the LOAEL of 0.005 mg/kg/day for PCBs, and 105 times below the chronic serious LOAEL of 0.02 mg/kg/day. The dose is also 1526 times below the LOAEL of 0.29 mg/kg/day for PBDEs.

The estimated doses for PCBs and PBDEs for an adult based on fish fillets are much lower than the estimated doses for whole fish for the general population (Table 3 and Appendix B, Table B3).

Recreational angler estimated dose

The highest estimated child dose (0 to 6 years old) *(worst case scenario)* for PCBs and PBDEs based on whole fish is 0.00084 mg/kg/day (Table 3 and Appendix B, Table B4), which exceeds the MRL of 0.00001 mg/kg/day for PCBs, and also exceeds the MRL of 0.0001 mg/kg/day for PBDEs. However, the estimated dose is 6 times below the LOAEL of 0.005 mg/kg/day for PCBs, and 24 times below the chronic serious LOAEL of 0.02 mg/kg/day. The dose is also 345 times below the LOAEL of 0.29 mg/kg/day for PBDEs.

The highest estimated adult dose *(worst case scenario)* for PCBs and PBDEs based on whole fish is 0.0003 mg/kg/day (Table 3 and Appendix B, Table B4), which exceeds the MRL of 0.00001 mg/kg/day for PCBs, and also exceeds the MRL of 0.0001 mg/kg/day for PBDEs. However, the estimated dose is 17 times below the LOAEL of 0.005 mg/kg/day for PCBs, and 67 times below the chronic serious LOAEL of 0.02 mg/kg/day. The dose is also 967 times below the LOAEL of 0.29 mg/kg/day for PBDEs.

The highest estimated adult dose for PCBs and PBDEs based on fish fillets is 0.00025 mg/kg/day (Table 3 and Appendix B, Table B4), which exceeds the MRL of 0.00001 mg/kg/day for PCBs, and also exceeds the MRL of 0.0001 mg/kg/day for PBDEs. However, the estimated dose is 20 times below the LOAEL of 0.005 mg/kg/day for PCBs, and 80 times below the chronic serious LOAEL of 0.02 mg/kg/day. The dose is also 1160 times below the LOAEL of 0.29 mg/kg/day for PBDEs.

The estimated adult recreational angler dose for PCBs and PBDEs based on fish fillets are much lower than the estimated doses for whole fish (Table 3 and Appendix B, Table B4).

A study suggests that there is a strong interactive effect between PBDEs and PCBs. However, researchers still need to verify whether this potential interaction exists before any conclusion can be drawn.[19, 20] For the purposes of this analysis, we assumed the default assumption of joint additivity risk from eating fish from the Spokane River. This risk is for people who eat fish according to the scenarios described in Appendix B, Tables B1 and B2. Based on these results, it is likely that the general population and recreational angler exposure scenarios for both children and adults indicate harmful non-cancer health effects from consuming fish (70% of the time eating fillet and 30% of the time eating whole fish) that contains both PCBs and PBDEs. The hazard index is greater than individual hazard quotients for either PCBs or PBDEs, and the dose of one or more of the individual chemicals are within one order of magnitude of its respective LOAEL for PCBs (see total sum, Table 3). Potential exposures are much higher for recreational anglers compared to the general population. In general, potential health risks are much lower when consumers eat only fish fillets compared to whole fish.

Table 3. Estimated dose in mg/kg/day compared to the LOAEL for both PCBs and PBDEs for the general population and a recreational angler exposure scenario, Spokane River, Spokane, Washington.

		General population estimated dose, total PCBs + PBDEs (mg/kg/day)	Recreational angler estimated Dose, total PCBs + PBDEs (mg/kg/day)	LOAEL (PCBs) mg/kg/day	LOAEL (PBDEs) mg/kg/day	General population, compared to PCBs dose (# of times below LOAEL)	Recreational angler compared to PCBs dose (# of times below LOAEL)	General population compared to PBDEs dose (# of times below LOAEL)	Recreational angler compared to PBDEs dose (# of times below LOAEL)
Whole fish	Child	0.00071	0.00084	0.005	0.29	7	6	409	345
	Adult	0.00019	0.0003			26	17	1526	967
Fillet	Child	0.00019	0.00046			26	17	1526	630
	Adult	0.00010	0.00025			50	20	2900	1160
Total sum [A]	Child	0.0009	0.0013			6	4	322	223
	Adult	0.00029	0.00055			17	9	3103	527

A – Total non-cancer risks represent the sum of whole fish and fillet. It assumes that 70% of the time fish is eaten as fillet and 30% of the time fish is eaten as whole fish.
PCBs – Polychlorinated biphenyls
PBDEs – Polybrominated diphenyl ethers
LOAEL – Lowest-observed-adverse effect level
mg/kg/day – milligrams per kilograms per day

Evaluating Cancer Risk

Theoretical cancer risk is estimated by calculating a dose similar to that described in the previous section and multiplying it by a cancer potency factor, also known as the cancer slope factor. Some cancer potency factors are derived from human population data. Others are derived from laboratory animal studies involving doses much higher than are encountered in the environment. Use of animal data requires extrapolation of the cancer risk obtained from these high dose studies down to real-world exposures. This process involves much uncertainty.

Current regulatory practice suggests that there is no "safe dose" of a carcinogen and that a very small dose of a carcinogen will give a very small cancer risk. Cancer risk estimates are, therefore, not yes/no answers but measures of chance (probability). Such measures, however uncertain, are useful in determining the magnitude of a cancer threat because any level of a carcinogenic contaminant carries associated risk. Validity of the "no safe dose" assumption for all cancer-causing chemicals is not clear. Some evidence suggests that certain chemicals considered to be carcinogenic must exceed a threshold of tolerance before initiating cancer. For such chemicals, risk estimates are not appropriate. More recent guidelines on cancer risk from EPA reflect the existence of thresholds for some carcinogens. However, EPA still assumes no threshold unless sufficient data indicate otherwise. This consultation assumes that there is no carcinogenic threshold for the chemicals of concern.

Cancer Risk = Estimated Dose x Cancer Slope Factor

Cancer risk is expressed as a probability. For instance, a cancer risk of 1×10^{-5} can be interpreted to mean that a person's overall risk of having cancer increases by 0.00001, or if 100,000 people were exposed, there might be 1 extra cancer in that population above background cancer rates. The reader should note that these estimates are for excess cancers that might result in addition to those normally expected in an unexposed population. Cancer risks quantified in this document are an upper-bound theoretical estimate. Actual risks are likely to be much lower.

Cancer health effects

Relatively few studies have assessed toxic interactions of carcinogenic chemicals in low dose ranges. Assuming additive effects, the cumulative theoretical cancer risk estimate for a mixture of chemicals is the sum of the individual chemical risk estimates. If the sum of the cancer risks exceed a level of concern for significant impact on lifetime cancer risk, the mixture constitutes a potential health hazard due to additivity. DOH's approach is to select a risk of 1 excess cancer in 10,000 people exposed (1×10^{-4}) as the level of concern for cumulative cancer risk.[6] DOH considers this as the point of departure (POD)[f] for risk levels considered to have a significant impact on lifetime cancer risk. It is not known if there are any interactive effects from concurrent exposures to PCBs and PBDEs on a cancer endpoint. Thus, DOH cannot assume additive effects for cancer (only cancer risks attributed to exposure to PCBs).

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[f] Point of departure is an estimated dose (usually expressed in human-equivalent terms) near the lower end of the observed range, without significant extrapolation to lower doses.

Based on the cancer risk estimates for total PCBs, theoretical cancer risks for a recreational angler eating both fillet and whole fish exceeds a risk of 1 excess cancer in 10,000 people exposed. This risk level is considered to have a significant impact on lifetime cancer risk (Appendix B, Table B6). This assumes recreational anglers eat fish from the Spokane River 70% of the time as fillet and 30% of the time as whole fish. Thus, recreational anglers will likely be at higher risk of developing excess cancer if PCB exposure is assumed from childhood into adulthood (i.e., average cancer risk over a 30 year lifetime exposure)[g].

Theoretical cancer risks for recreational anglers that consume only fillets of fish from the Spokane River do not exceed a risk level of 1 excess cancer in 10,000 people exposed. This risk level is not considered to have a significant impact on lifetime cancer risk (Appendix B, Table B6). Similarly, theoretical cancer risks for general population consumers eating both fillets and whole fish from the Spokane River also do not exceed a risk of 1 in 10,000 (Appendix B, Table B5).

It should be noted that the range of cancer risks considered acceptable by EPA is 1 excess cancer per million people exposed to 1 excess cancer per 10,000 people exposed ($1x10^{-6}$ to $1x10^{-4}$).

Metals

DOH evaluated metals (arsenic, cadmium, lead, and zinc) in fish tissue using the maximum value reported in a 2007 health consultation.[5] With the exception of zinc (slight exceedance), EPA screening levels for these metals were not exceeded using subsistence level consumption rates (142 g/day).[5] However, zinc was not determined to be a contaminant of concern for the following reasons, which also apply to all metals:

1) The use of the maximum concentrations coupled with subsistence consumption rates overestimates possible health effects.

2) EPA's subsistence screening value ingestion rate (142 g/day) is more than 3 times the recreational angler's ingestion rate of 42 g/day (this is the average ingestion rate for recreational anglers who fish along the Spokane River).[21, 22]

3) A recreational angler screening value would be much lower than EPA's subsistence screening value and the hazard quotient (i.e., the ratio of an exposure estimate to the appropriate MRL) would be much less than one.

4) Using the mean concentration of the metals would further decrease the exposure dose to a recreational angler thereby further reducing the hazard quotient below one. Thus, any addition from these metals would be negligible to the overall non-cancer risk.

[g] The cancer risk calculation is based on 30 years of exposure and was averaged over a lifetime of 70 years.

5) Fish accumulate lead mostly in the gill, liver, kidney, and bone. Lead concentrations in some marine fish are higher in gills and skin than in other tissues, but this may be largely due to adsorption. Lead concentration uncertainty is an issue for large scale suckers. These fish are bottom feeders and during sample preparation, larger amounts of sediment have been observed in their digestive tracts compared to other fish.[23] Sediment in the digestive tracts of these fish can affect the concentration of metals (particularly lead) during analysis.

Appendix C, Table C1 shows maximum concentrations of metals found in Spokane River fish. Only zinc exceeded comparison values. The lead maximum concentration occurred between the Upriver Dam to the stateline. In the 2007 health consultation, DOH concluded that "*a public health hazard*" exists for pregnant women and children who consume whole fish contaminated with lead from the Spokane River between the Upper Long Lake and the stateline.[5] As a result of this, DOH recommended fish consumption advisories for locations where PCBs, PBDEs, and metals were present in fish at levels of health concern. The fish advisory that is currently in place is based mainly on PCBs (the contaminant risk driver). The advisory recommends cleaning and preparing fish to reduce exposure to PCBs and other contaminants that collect in the fat of fish as a prudent health measure. Therefore, lead is not considered for analysis in the multiple chemical approach of this report. Reasons for not evaluating lead include:

- Lead is found mostly at higher levels in whole fish tissue versus fillet.
- The highest lead concentration occurs between the Upriver Dam to the stateline. At this location the current fish advisory warns against any consumption of fish – only catch and release.
- Health effects due to lead exposure are evaluated differently than for other chemicals such as PCBs and PBDEs. To evaluate the potential for harm, a computer model called Integrated Exposure Uptake Biokinetic Model (IEUBK) is used to predict blood lead levels in children. It is intended to help evaluate the risk of lead poisoning for an average child who is exposed to lead in the environment.
- There are no reference doses for lead; thus, it is not possible to calculate an exposure dose related to lead (i.e., it is not possible to add lead into the multiple chemical approach and/or interactive effects of lead with PCBs and PBDEs).
- Lead is stored mostly in the bone of fish; therefore, the fish advisory recommends eating fish fillets instead of whole fish.
- PCBs are the contaminant risk driver for Spokane River fish, except at the stateline location. Since DOH recommends no fish consumption at this site, any advice provided for fish consumption based on PCBs will also be protective of excessive lead exposure.

Children's Health Considerations

Children's health was considered during this health consultation and the exposure scenarios treated children as the most sensitive exposed population. The potential for exposure and subsequent adverse health effects often increases for younger children

compared with older children or adults. ATSDR and DOH recognize that children are more susceptible to contaminant exposures than adults. The following factors contribute to this vulnerability:

- Children are more likely to play outdoors in contaminated areas by disregarding signs and wandering onto restricted locations.
- Children often bring food into contaminated areas, resulting in hand-to-mouth activities.
- Children are smaller and receive higher doses of contaminant exposures per body weight.
- Children are shorter than adults; therefore, they have a higher possibility of breathing in dust and soil.
- Fetal and child exposure to contaminants can cause permanent damage during critical growth stages.

These unique vulnerabilities of infants and children demand special attention in communities that have contaminated water, food, soil, or air.

Uncertainty on cumulative effects

DOH recognizes there are uncertainties in evaluating the cumulative effects of chemical mixtures. Because relatively few chemical mixture studies have assessed toxic interactions in low dose ranges, there is uncertainty when assessing the interactive effects of exposures to environmental contaminants in fish.

DOH used protective assumptions to determine the public health implications of multiple exposures to contaminants in fish from the Spokane River. In general, there are uncertainties in evaluating the interactive effects for low-level environmental exposures; thus, the true risk to the public is difficult to assess accurately and depends on a number of factors such as the concentration of chemicals, consumption rates, frequency and duration of exposure, and the genetic susceptibility of an individual.

Conclusions

DOH reached three important conclusions in this health consultation:

- DOH concludes that eating both fillet and whole fish containing PCBs from the Spokane River for about 30 years could harm recreational angler's health due to cancer health effects. This is *a public health hazard*. Recreational anglers who eat fish from the Spokane River 365 days per year at a rate of 42 grams per day (whole fish 30% of the time and fillet 70% of the time), will have an increased risk of developing cancer (average cancer risk for approximately 30 year lifetime exposure)[h]. DOH considers that the estimated theoretical cancer risk exceeds a risk of 1 excess

[h] The cancer risk calculation is based on 30 years of exposure and is being averaged over an entire lifetime of 70 years.

cancer in 10,000 people exposed. This risk level is considered to have a significant impact on lifetime cancer risk. People who eat only whole fish will be at higher risk than those who eat fillets because whole fish contains higher levels of contaminants than fillets.

  - It should be noted that these estimates exceed EPA's acceptable cancer risk of 1 excess cancer per 10,000 people exposed (1×10^{-4}). Theoretical cancer risks for recreational anglers and the general population[i] that eat fish fillets from the Spokane River are much lower. The estimated theoretical cancer risk for recreational anglers who eat only fillets of fish they catch from the Spokane River falls within EPA's acceptable range of 1 excess cancer in a 1,000,000 people exposed (1×10^{-6}) to 1 excess cancer in 10,000 people exposed (1×10^{-4}) (Appendix B, Tables B5 and B6).

- DOH concludes that people who eat fish (whole fish 30% of the time and fillet 70% of the time) from the Spokane River 365 days per year at a rate of 17.5 grams per day for general population and 42 grams per day for recreational anglers for more than a year at some Spokane River locations where fish contain high levels of PCBs and PBDEs is likely to harm people's health due to non-cancer health effects. This is *a public health hazard*. The hazard index is greater than individual hazard quotients for either PCBs or PBDEs, and the dose of one or more of the individual chemicals are within one order of magnitude of its respective LOAEL for PCBs (see total sum, Table 3). In general, potential health risks are much lower when consumers eat only the fillets of fish caught in the Spokane River as compared to those who eat whole fish .

- DOH concludes that eating Spokane River fish could harm people's health from the combination of chemicals (i.e., PCBs, PBDEs, and metals) with similar target organs toxicity. "This is a *public health hazard*." While evidence is lacking that PBDEs interactively enhance the toxicity of PCBs, DOH is taking a precautionary approach by assuming joint additivity.[j] Since the toxicity is likely no less than that predicted for single chemical toxicity, DOH choose to err on the side of concern/prevention.

Recommendations

1. The fish advisory for the Spokane River should remain in place based on the 2007 health consultation and this evaluation on the cumulative effects of PCBs and PBDEs. For more information, visit the DOH fish consumption website: http://www.doh.wa.gov/fish.

    - DOH recommends against any consumption of fish between the Idaho border and Upriver Dam. For the reach between Upriver Dam and Nine Mile Dam,

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[i] For the general population and a recreational angler is assumed that fish is eaten 365 days per year at a rate of 17.5 grams per day and 42 grams per day, respectively.
[j] Although, a study suggests that there is a strong interactive effect between PBDEs and PCBs, researchers still need to verify whether this potential interaction exist before any conclusion can be drawn.[19,20]

DOH advises against eating more than one meal per month of any species. DOH advises consumers not to eat large scale sucker at this location. For the reach between Nine Mile Dam and Long Lake (Upper and Lower Long Lake), DOH advises no more than one meal per month for large scale sucker and brown trout, and no more than one meal per week for mountain whitefish.

- *There is a statewide freshwater bass and northern pikeminnow advisory due to mercury. Limit largemouth and smallmouth bass to two meals per month; do not consume northern pikeminnow. Check for fish advisories at* www.doh.wa.gov/fish.

- In order to reduce exposure from PCBs and PBDEs in all fish, DOH recommends eating fillets instead of whole fish, removing the skin, and cleaning all fish. DOH also recommends that the fish be prepared by grilling, broiling, or baking so the fat can drip off and do not use fat in gravy or sauces.

2. DOH recommends monitoring for PBDEs and PCBs continue in the Spokane River.

3. Future updates of the Spokane River fish advisory should be based on long-term fish tissue monitoring trends.

Public Health Action Plan

Actions completed

- In 2008, DOH and the Spokane Regional Health District updated the fish consumption advisory based on current PCB information. This advisory is already in place along the Spokane River and recommends against any consumption of fish between the Idaho border and Upriver Dam. For the reach between Upriver Dam and Nine Mile Dam, DOH advises consumers against eating more than one meal per month of any species. DOH also advises consumers not to eat large scale sucker at this location. For the reach between Nine Mile Dam and Long Lake (Upper and Lower Long Lake), DOH advises no more than one meal per month for large scale sucker and brown trout, and no more than one meal per week for mountain whitefish.
  - *There is a statewide freshwater bass and northern pikeminnow advisory due to mercury. Limit largemouth and smallmouth bass to two meals per month; do not consume northern pikeminnow. Check for fish advisories at* www.doh.wa.gov/fish.
- In 2009, DOH commented and provided feedback on the Spokane River Public Guide "Toxic Chemicals and Heavy Metals in the Spokane River."

- In 2009, DOH sent a memo response regarding fish contamination in the Spokane River and cumulative risks to the Center for Justice, and Lands Council, Spokane, Washington.

- In 2009, DOH sent a memo response to the Center for Justice on the draft "Fish Contamination in the Spokane River and Related Effects on Human Health submitted by Peter deFur, Environmental Stewardship Concepts." In this memo, DOH responded that we will be evaluating the Spokane River data to look at cumulative (additive) risk for immune system and developmental effects based on multiple chemicals using the most recent 2005 fish data for the Spokane River.

Actions planned

- DOH will provide copies of this health consultation to the Center for Justice, Environmental Stewardship Concepts, Washington State Department of Ecology, Spokane Regional Health District, and other concerned parties.

- DOH may develop additional educational materials on fish consumption for the Spokane River.

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Appendix A

Contaminant Screening Process

The information in this section describes how contaminants of concern in fish were chosen from a set of many contaminants. A contaminant's maximum concentration in fish was compared to a screening value (comparison value). If the contaminant's concentration was greater than that value, it was considered further.

Comparison values were calculated using EPA's chronic reference doses (RfDs) and cancer slope factors (CSFs). RfDs represent an estimate of daily human exposure to a contaminant below which non-cancer adverse health effects are unlikely.

This screening method ensured consideration of contaminants that may be of concern for fish consumers. The equations below show how comparison values were calculated for both non-cancer and cancer endpoints associated with consumption of fish.

$$CV_{\text{non-cancer}} = \frac{RfD * BW}{SIR * CF}$$

$$CV_{\text{cancer}} = \frac{\text{Risk Level} * BW}{SIR * CF * CPF}$$

Where CV for non-cancer:

RfD = oral reference dose (mg/kg-day).
BW = mean body weight of the general population or subpopulation of concern (kg)
SIR = mean daily consumption rate of the species of interest by the general population or subpopulation of concern averaged over a 70-year lifetime (kg/d)
CF = conversion factor (kg/g)
CPF = cancer potency factor

Where CV for cancer:

Risk Level (RL) = an assigned level of maximum acceptable individual lifetime risk (e.g., RL = 10^{-5} for a level of risk not to exceed one excess case of cancer per 100,000 individuals exposed over a 70-year lifetime.

Table A1. Parameters used to calculate comparison values in the Spokane fish contaminant screening process, Spokane River, Spokane, Washington.

Abbreviation	Parameter	Units	Value	Comments
CV	Comparison Value	mg/kg	Calculated	
RfD	Reference Dose	mg/kg-day	Chemical Specific	EPA
SIR	Fish Ingestion Rate	g/day	142.4 42 17.5	Subsistence person Recreational angler General population
BW	Bodyweight	kg	70 and 60	Adult and adult pregnant women
			15 and 41	Child and older child
CF	Conversion Factor	kg/g	0.001	kilograms per gram
AT	Averaging Time	Days	25550	Days in 70 year lifetime
EF	Exposure Frequency	Days	365	Days per year
ED	Exposure Duration	Years	15 (adult)	Years consuming fish
			10 (older child)	
			5 (child)	
Risk Level	Lifetime cancer risk	Unitless	$1x10^{-5}$	
CPF	Cancer Potency Factor	kg-day/mg	Chemical Specific	EPA

Appendix B

Exposure dose calculations and assumptions

Average and upper-bound general population exposure scenarios were evaluated for consumption of fish from Spokane River. Exposure assumptions given in Table B1 below were used with the following equations to estimate contaminant doses associated with fish consumption.

$$\text{Dose}_{\text{(non-cancer (mg/kg-day)}} = \frac{\text{C x CF}_1 \text{ x IR x CF}_2 \text{ x EF X ED}}{\text{BW x AT}_{\text{non-cancer}}}$$

$$\text{Dose}_{\text{(cancer (mg/kg-day)}} = \frac{\text{C x CF}_1 \text{ x IR x CF}_2 \text{ x EF X ED}}{\text{BW x AT}_{\text{cancer}}}$$

Table B1. Exposure assumptions used to evaluate total PCBs and PBDEs in fish from the Spokane River, Spokane, Washington.

Parameter	Value	Unit	Comments
Concentration (C)	Variable	ug/kg	Mean concentration value assumes that rainbow trout is consumed 70% of the time, while other species of fish found in the Spokane River are consumed 30% of the time
Conversion Factor$_1$ (CF$_1$)	0.001	mg/ug	Converts contaminant concentration from micrograms (ug) to milligrams (mg)
Ingestion Rate (IR) –	42 g/day	g/kg/day	Average recreational anglers (42 g/day) [22, 21]
	17.5 g/day		Average general U.S. population
	9.0 g/day		Child 0-6 years old
	7.0 g/day		Older child 6 to 17 years old
Body weight	70	kg	Adult
	15		Child
	41		Older child
Conversion Factor$_2$ (CF$_1$)	0.001	mg/ug	Converts contaminant concentration from micrograms (ug) to milligrams (mg)
Conversion Factor$_2$ (CF$_2$)	0.001	kg/g	Converts mass of fish from grams (g) to kilograms (kg)
Exposure Frequency (EF)	365	days/year	Assumes daily exposure consistent with units of ingestion rate given in g/day – 70% - 255.5 days 30% - 109.5 days
Exposure Duration (ED)	15	years	Number of years eating fish (adult)
	5		Number of years eating fish (child)
	10		Number of years eating fish (older child)
Averaging Time$_{non\text{-}cancer}$ (AT)	10950	days	30 years
Averaging Time$_{cancer}$ (AT)	25550	days	70 years
Oral Reference Dose (RfD)	Contaminant-specific	mg/kg/day	Source: ATSDR, EPA, IRIS
Cancer Risk	1x 10^{-5}	unitless	Target Cancer Risk
Cancer Slope Factor (CSF)	Contaminant-specific	mg/kg-day-1	Source: EPA

Hazard quotient equation:

$$HQ = \frac{\text{Estimated Dose (mg/kg-day)}}{\text{RfD (mg/kg-day)}}$$

Table B2. Derivation of consumption rates for a recreational angler and the general population.

	Reported all fish consumption rate (g/day)	Calculated consumption rate in g/kg/day
Recreational angler	42.0	0.6
General population Adult	17.5	0.25
Child (0-6 yrs)	7.0	0.466
Older child (6-17 yrs)	9.0	0.22

Recreational angler	Reported all fish consumption rate (g/day)	Calculated consumption rate in g/kg/day
Adult	42.0	0.6
Child (0-6 yrs)	16.8	1.12
Older child (6-17 yrs)	21.6	0.5

DOH used a ratio of a recreational angler to derive child and older child consumption rates. This ratio is based on consumption rate of 42 g/day for a recreational angler (e.g., DOH calculated consumption rates in g/kg/day for a child and older child eating at the same ratio for the general population). For example, 17.5 g/day divided by 7 g/day (child) = 2.5, then the consumption rate for a recreational angler of 42 g/day was divided by 2.5, which corresponds to 16.8 g/day.

EPA's reference dose values for PBDE congeners:

- BDE-47 (tetrabromodiphenyl ether) reference dose (RfD) corresponds to 1.0 x 10^{-4} mg/kg-day or 0.1 ug/kg-day (critical effect, neurobehavioral effects)
- BDE-99 (pentabromodiphenyl ether) RfD corresponds to 1.0 x 10^{-4} mg/kg-day or 0.1 ug/kg-day (critical effect, neurobehavioral effects)
- BDE-153 (hexabromodiphenyl ether) RfD corresponds to 2.0 x 10^{-4} mg/kg-day or 0.2 ug/kg-day (critical effect, neurobehavioral effects)
- BDE-209 (decabromodiphenyl ether) RfD corresponds to 7.0 x 10^{-3} mg/kg-day or 7 ug/kg-day (critical effect, neurobehavioral effects)

Table B3. Non-cancer hazards associated with the general population from exposure to contaminants of concern in Spokane River fish, Spokane County, Washington.

Contaminant		**Mean Concentration (ppm) wet weight †**		**Estimated Dose** (mg/kg/day) general population Average	**MRL or RfD (mg/kg/day)**	**Hazard quotient** general population Average
Total PCBs	Fillet [a]	0.1617	Child	5.3×10^{-5}	2×10^{-5} [e]	**2.6**
			Older child	2.5×10^{-5}		**1.2**
			Adult	2.8×10^{-5}		**1.4**
	Whole [b]	0.2838	Child	4.0×10^{-5}		**2.0**
			Older child	1.9×10^{-5}		**0.9**
			Adult	2.1×10^{-5}		**1.1**
Total PBDEs	Fillet [c]	0.4236	Child	1.4×10^{-4}	1.0×10^{-4} [f]	**1.4**
			Older child	6.5×10^{-5}		0.7
			Adult	7.4×10^{-5}		0.7
	Whole [d]	2.2	Child	3.1×10^{-4}		**3.1**
			Older child	1.5×10^{-4}		**1.5**
			Adult	1.7×10^{-4}		**1.7**
Cumulative hazard Index (based on fillets)*			Child	1.9×10^{-4}		**4.0**
			Older child	9.0×10^{-5}		**1.9**
			Adult	1.0×10^{-4}		**2.1**
Cumulative hazard Index (based on whole fish)*			Child	7.1×10^{-4}		**5.1**
			Older child	1.1×10^{-4}		**2.4**
			Adult	1.9×10^{-4}		**2.8**

† See uncertainty section for recreational anglers that consume fish from the Spokane River
Exposure duration is based on 6, 10 and 30 years exposures for a child, older child and adult respectively.
[a] – **Fillet** – Total polychlorinated biphenyl (PCB) concentration calculated based on consumption of rainbow trout (fillet) (70%), plus mountain white fish (fillet) (15%), and brown trout (fillet) (15%) using the maximum value of the mean concentration for each species.
[b] – **Whole** – Total PCB concentration calculated based on consumption of large scale sucker (whole body) (15%), and bridgelip sucker (whole body) (15%) using the maximum value of the mean concentration for each species.
[c] – **Fillet** – Total polybrominated diphenyl ether (PBDE) concentration calculated based on consumption of rainbow trout (fillet) (70%), plus mountain white fish (fillet) (15%), and brown trout (fillet) (15%) using the maximum value of the mean concentration for each species.
[d] – **Whole** – Total PBDE concentration calculated based on consumption of rainbow trout (whole body) (70%), large scale sucker (whole body) (15%), and mountain whitefish (whole body) (15%) using the maximum value of the mean concentration for each species.
Bold – Cumulative hazard index exceeds one
[e] – ATSDR's chronic oral Minimal Risk Level (MRL) is used
[f] – **Reference Dose** (RfD) for PBDE-47 was used in evaluating total PBDEs. See Appendix A, EPA's reference dose values for PBDE congeners
* Sum of hazard index and target-organ toxicity doses (TTDs) for fillet and whole fish– (i.e., for immunological and developmental) for repeated oral exposures to chemicals of concern (PCBs and PBDEs.) It represents the sum of fillet for both PCBs and PBDEs, and whole fish for both PCBs and PBDEs. Estimation of total non-cancer risks assumes endpoints are similar for immunological and developmental toxicity.

Table B4. Non-cancer hazards associated with a recreational angler from exposure to contaminants of concern in the Spokane River fish, Spokane County, Washington.

Contaminant		**Mean Concentration (ppm) Wet weight**		**Estimated Dose** (mg/kg/day) Recreational angler	**MRL or RfD (mg/kg/ day)**	**Hazard quotient** Recreational angler
Total PCBs	Fillet [a]	0.1617	Child	1.3×10^{-4}	2×10^{-5} [e]	**6.3**
			Older child	6.0×10^{-5}		**3.0**
			Adult	6.8×10^{-5}		**3.4**
	Whole [b]	0.2838	Child	9.5×10^{-5}		**4.8**
			Older child	4.5×10^{-5}		**2.2**
			Adult	5.1×10^{-5}		**2.6**
Total PBDEs	Fillet [c]	0.4236	Child	3.3×10^{-4}	1.0×10^{-4} [f]	**3.3**
			Older child	1.6×10^{-4}		**1.6**
			Adult	1.8×10^{-4}		**1.8**
	Whole [d]	2.2	Child	7.4×10^{-4}		**7.4**
			Older child	3.5×10^{-4}		**3.5**
			Adult	4.0×10^{-4}		**4.0**
Cumulative hazard Index (based on fillets)*			Child	4.6×10^{-4}		**9.6**
			Older child	2.2×10^{-4}		**4.6**
			Adult	2.5×10^{-4}		**5.2**
Cumulative hazard Index (based on whole fish)*			Child	8.4×10^{-4}		**12.2**
			Older child	4.0×10^{-4}		**5.7**
			Adult	3.0×10^{-4}		**6.6**

† See uncertainty section for recreational anglers that consume fish from the Spokane River
Exposure duration is based on 6, 10 and 30 years exposures for a child, older child and adult respectively.
[a] – **Fillet** – Total Polychlorinated biphenyl (PCB) concentration calculated based on consumption of rainbow trout (fillet) (70%), plus mountain white fish (fillet) (15%), and brown trout (fillet) (15%) using the maximum value of the mean concentration for each species.
[b] – **Whole** – Total PCB concentration calculated based on consumption of large scale sucker (whole body) (15%), and bridgelip sucker (whole body) (15%) using the maximum value of the mean concentration for each species.
[c] – **Fillet** – Total Polybrominated Diphenyl Ether (PBDE) concentration calculated based on consumption of rainbow trout (fillet) (70%), plus mountain white fish (fillet) (15%), and brown trout (fillet) (15%) using the maximum value of the mean concentration for each species.
[d] – **Whole** – Total PBDE concentration calculated based on consumption of rainbow trout (whole body) (70%), large scale sucker (whole body) (15%), and mountain whitefish (whole body) (15%) using the maximum value of the mean concentration for each species.
[e]- ATSDR's chronic oral Minimal Risk Level (MRL) for Aroclor 1254 for total PCBs
[f] – **Reference Dose (**RfD) for PBDE-47 was used in evaluating total PBDEs. See Appendix A, EPA's reference dose values for PBDE congeners
Bold – Cumulative hazard index exceeds one
* Sum of hazard index and target-organ toxicity doses (TTDs) for fillet and whole fish– (i.e., for immunological and developmental) for repeated oral exposures to chemicals of concern (PCBs and PBDEs.) It represents the sum of fillet for both PCBs and PBDEs, and whole fish for both PCBs and PBDEs. Estimation of total non-cancer risks assumes endpoints are similar for immunological and child developmental toxicity.

Table B5. Theoretical cancer risk for the general population associated with exposure to contaminants of concern in Spokane River fish, Spokane County, Washington.

Contaminant		Mean Concentration (ppm)	Scenarios General population	Cancer slope factor (CSF) $(mg/kg/day)^{-1}$	Cancer risk General population
Total PCBs	Fillet	0.1617	Child	2.0	7.6×10^{-6}
			Older child		7.1×10^{-6}
			Adult		1.2×10^{-5}
	Total theoretical cancer risk (fillet)†				2.7×10^{-5}
	Whole	0.2838	Child	2.0	5.7×10^{-6}
			Older child		5.3×10^{-6}
			Adult		9.1×10^{-6}
	Total theoretical cancer risk (whole)†				2.0×10^{-5}
Total theoretical cancer risk (both fillet and whole fish) [A]					4.7×10^{-5}

Cancer risks represent cumulative lifetime exposure from childhood to adulthood.
† - Exposure duration is based on 5, 10 and 15 years exposures for a child, older child and adult respectively, resulting in a total theoretical cancer risk for both fillet and whole fish of 30 year exposure.
[A] – Total theoretical cancer risks are based on consumption of fish for both fillet and whole fish. This is assuming recreational anglers eat fish 70% of the time as fillet and 30% of the time as whole fish.

Table B6. Theoretical cancer risk for recreational anglers associated with exposure to contaminants of concern in Spokane River fish, Spokane County, Washington.

Contaminant		Mean Concentration (ppm)	Scenarios Recreational angler	Cancer slope factor (CSF) $(mg/kg/day)^{-1}$	Cancer risk (recreational angler)
Total PCBs	Fillet	0.1617	Child	2.0	1.8×10^{-5}
			Older child		1.7×10^{-5}
			Adult		2.9×10^{-5}
	Total theoretical cancer risk (fillet) †				6.4×10^{-5}
	Whole	0.2838	Child		1.4×10^{-5}
			Older child		1.3×10^{-5}
			Adult		2.2×10^{-5}
	Total theoretical cancer risk (whole) †				4.8×10^{-5}
Total theoretical cancer risk (both fillet and whole fish) [A]					1.1×10^{-4}

Cancer risks represent cumulative lifetime exposure from childhood to adulthood
† - Exposure duration is based on 5, 10 and 15 years exposures for a child, older child and adult respectively, resulting in a total theoretical cancer risk for both fillet and whole fish of 30 year exposure.
[A] – Total theoretical cancer risks are based on consumption of fish for both fillet and whole fish. This is assuming recreational anglers eat fish 70% of the time as fillet and 30% of the time as whole fish.

Appendix C

Table C1. Summary of metals in Spokane River fish (2005) compared to subsistence consumption screening values, Spokane, Spokane County, Washington.

Contaminant	Maximum Concentration (mg/kg)	Subsistence Comparison Value (mg/kg) [2]	RfD (mg/kg/day)	Contaminant of concern
Arsenic, total	0.39	NA	3.0E-04	No
Arsenic, inorganic 10% of total‡‡	0.039	0.147 (non-cancer)	3.0E-04	No
Cadmium	0.24	0.491	1.0E-03	No
Lead †	6.7	NA	NA	**Yes**
Zinc ‡	**165**	147.8	0.3	No

NA – Not available
mg/kg - milligrams per kilograms; ppm = parts per million
RfD – Reference dose
BOLD - Values exceed comparison value
† IEUBK – The Integrated Exposure Uptake Biokinetic Model for Lead in Children is used to predict blood lead levels in children, thus, there is no comparison value for lead. Blood lead was evaluated in a previous health consultation in 2006 using the maximum concentration at several locations in the Spokane River. The concentration was found in large scale sucker (i.e., whole fish) at the stateline location and between Ninemile and Upriver Dam. At these locations, the fish advisory recommends only catch and release and/or has meal limit restrictions.
‡ Zinc is an essential nutrient found in almost every cell. The Recommended Dietary Allowance (RDA), one of the Dietary Reference Intakes (DRIs), is the average daily dietary intake level that is sufficient to meet the nutrient requirements of nearly all (97-98%) healthy individuals. For infants 0 to 6 months, the DRI is in the form of an Adequate Intake (AI), which is the mean intake of zinc in healthy, breastfed infants. The AI for zinc for infants from 0 through 6 months is 2.0 milligrams (mg) per day. The 2001 RDAs for zinc for infants 7 through 12 months, children, and adults in mg per day are: 7 months through 3 years, the AI is 3.0 milligrams (mg) per day; 4 to 8 years the AI is 5 milligrams (mg) per day; 9 to 13 years the AI is 8 milligrams (mg) per day; 14 years and up the AI is 13 milligrams (mg) per day. Results of two national surveys, the National Health and Nutrition Examination Survey (NHANES III 1988-91)[7] and the Continuing Survey of Food Intakes of Individuals (1994 CSFII), [8] indicate that most infants, children, and adults consume recommended amounts of zinc.
‡‡ Cancer values for inorganic arsenic were not evaluated because there is not data for arsenic speciation in fish from Spokane River. The majority of arsenic in finfish is presumed to be organic arsenic, which is less toxic than inorganic forms.

Appendix D

Table D1. PBDE congeners found in fillet and whole fish at the Spokane River site, Spokane, Spokane County, Washington.

Sample type and species	PBDE congeners (ug/kg)			
Fillet	BDE-47	BDE-99	BDE-100	BDE-153
Rainbow trout	35	39	9.4	2.4
Rainbow trout	12	11	3.9	0.9
Mountain whitefish	144	172	31	4.9
Rainbow trout	182	172	39	7.5
Mountain whitefish	443	449	111	17
Mountain whitefish	76	69	19	2.7
Brown trout	86	41	16.8	2.2
Smallmouth bass	26	8.9	3.9	0.5
Mountain whitefish	54	45	13.7	2.9
Smallmouth bass	29	14	6.2	1.1
Whole	BDE-47	BDE-99	BDE-100	BDE-153
Large scale sucker	156	0.6	26	5.9
Large scale sucker	125	0.4	20.5	2.5
Large scale sucker	74	0.4	12	1.2
Bridgelip sucker	423	2.8	64	13
Rainbow trout	934	882	182	45
Mountain whitefish	1,932	2,164	537	88
Large scale sucker	471	0.4	72	5.1
Large scale sucker	162	0.5	22.1	2.2

PBDE – Polybrominated Diphenyl Ether
Brominated Diphenyl Ether (BDE)-47, -99, -100, -153
ug/kg – milligrams per kilograms

Figure D1. PBDE congeners in fillet fish sampled during August through November 2005 in ug/kg at Spokane River, Spokane County, Washington.

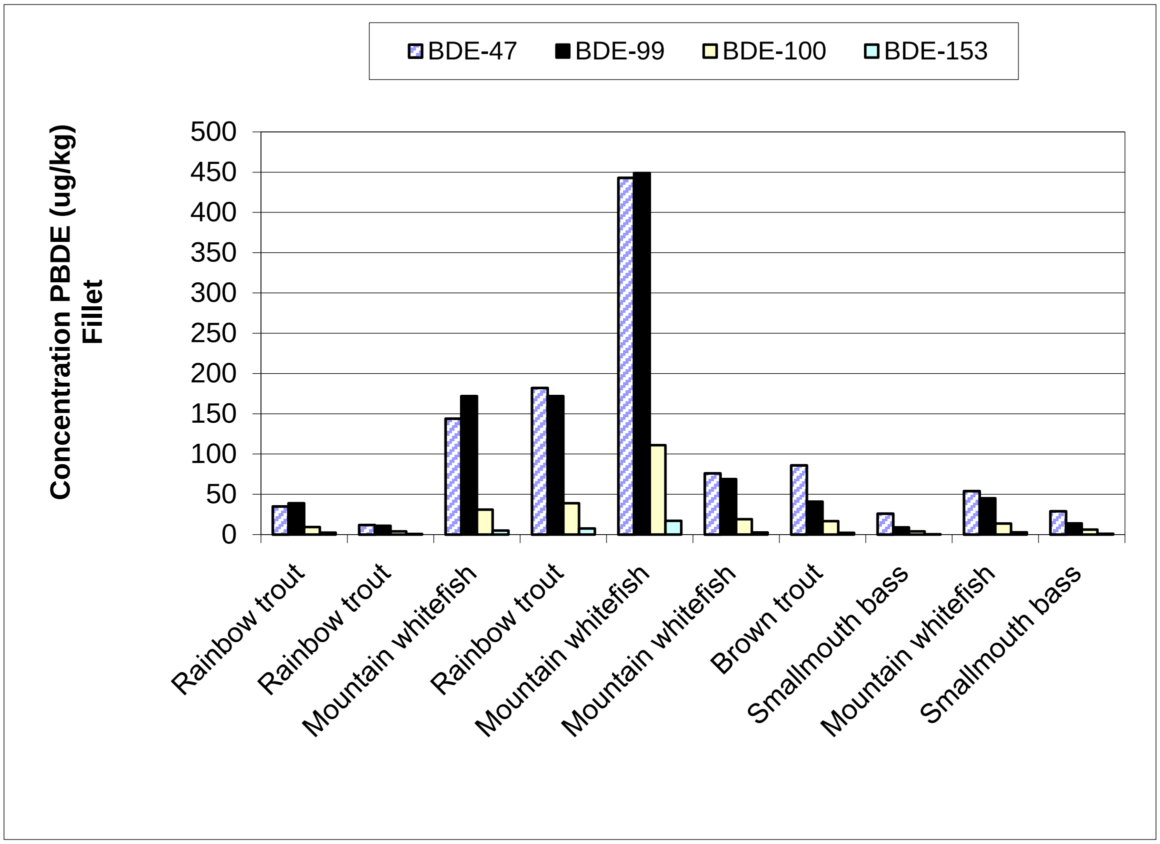
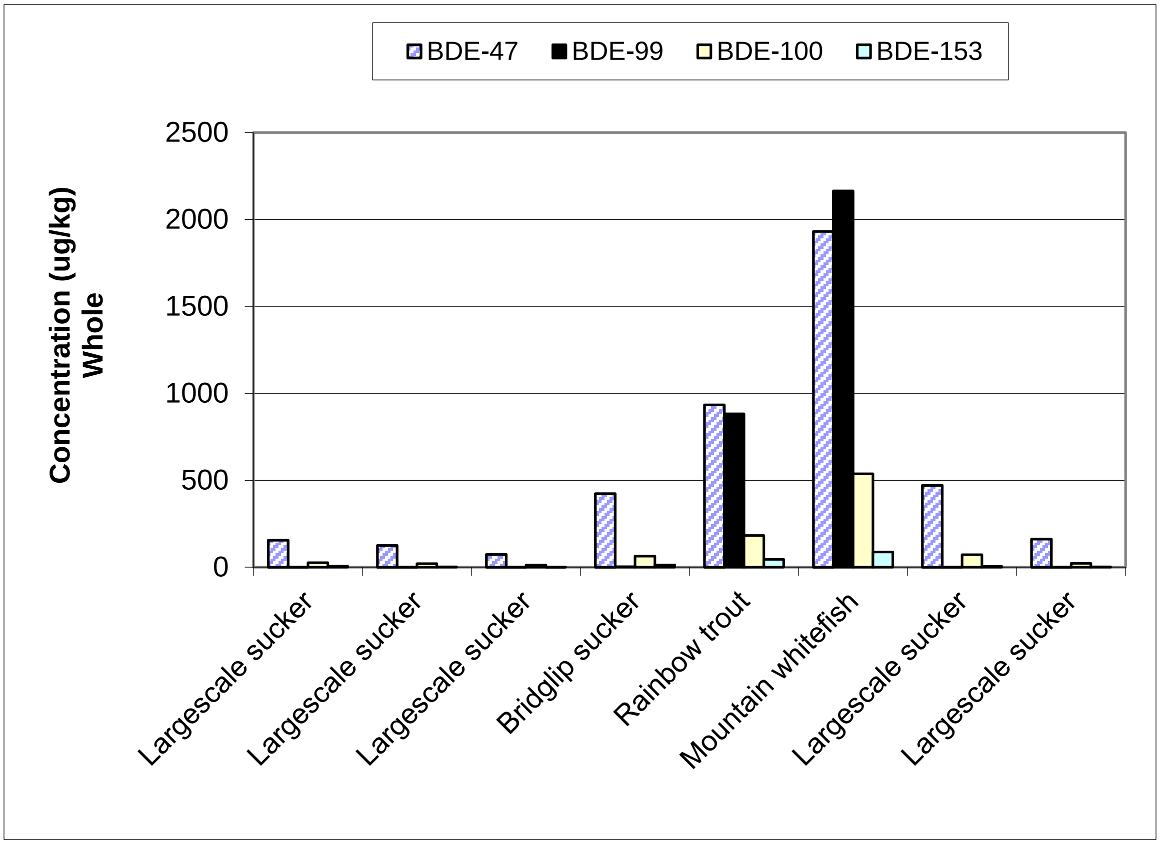


Figure D2. PBDE congeners in whole fish sampled during August through November 2005 in ug/kg at Spokane River, Spokane County, Washington.



Appendix E

Chemical Specific Information and Toxicity

Polychlorinated biphenyls (PCBs)

Polychlorinated biphenyls (PCBs) are persistent environmental contaminants that are ubiquitous in the environment due to intensive industrial use. PCBs were used as commercial mixtures (Aroclors) that contain up to 209 different chlorinated biphenyl congeners which are structurally similar compounds that vary in toxicity. A smaller subset of 50 to 60 congeners is commonly found in Aroclor mixtures.[24] Each congener has a biphenyl ring structure but differs in the number and arrangement of chlorine atoms substituted around the biphenyl ring. The name Aroclor 1254, for example, means that the molecule contains 12 carbon atoms (the first 2 digits) and approximately 54% chlorine by weight (second 2 digits).[25] Each mixture (1016, 1242, 1254, and 1260) contained many different PCB congeners. PCBs are lipid soluble and very stable; their stability depends on the number of chlorine atoms and their position on the biphenyl molecule. PCBs' lipophilic character and resistance to metabolism enhances concentration in the food web and exposure to humans and wildlife.

In 1971, the sole U.S. producer of PCBs (Monsanto Chemical Company) voluntarily stopped open-ended uses of PCBs and in 1977 ceased their production. Because PCBs do not burn easily and are good insulators, they were commonly used as lubricants and coolants in capacitors, transformers, and other electrical equipment. Old capacitors and transformers that contain PCBs are still in operation. Over the years, PCBs have been spilled, illegally disposed, and leaked into the environment from transformers and other electrical equipment. PCBs in the environment have decreased since the 1970's but are still detectable in our air, water, soil, food, and in our bodies.

The breakdown of PCBs in water, sediment, and soil occurs over many years and is often incomplete. Lower chlorinated PCBs are more easily broken down in the environment, while adsorption of PCBs generally increases as chlorination of the compound increases. The highly chlorinated Aroclors (1248, 1254, and 1260) resist both chemical and biological degradation in the environment. Microbial degradation of highly chlorinated Aroclors to lower chlorinated biphenyls has been reported under anaerobic conditions, as has the mineralization of biphenyl and lower chlorinated biphenyls by aerobic microorganisms. Although they are slow processes, volatilization and biodegradation are the major pathways of removal of PCBs from water and soil,[25] and volatilization is more significant for lower chlorinated congeners. In water, photolysis appears to be the only viable chemical degradation process. The chemical composition of the original Aroclor mixtures released to the environment changes over time since the individual congeners degrade and partition at different rates.[25]

Many PCB congeners persist in ambient air, water, marine sediments, and soil at low levels throughout the world. The half-life of PCBs (the time it takes for one-half of the PCBs to breakdown) in the air is 10 days or more, depending on the type of PCB. PCBs

in the air can be carried long distances and may be deposited onto land or water. Once in water, most PCBs tend to adsorb to organic particles and sediments. The rate and extent of degradation is a function of temperature and the degree to which PCBs are bound to organic material and hence unavailable for degradation.

In Spokane River and other waterbodies, sediment-associated PCBs are accumulated in the bodies of aquatic organisms, which are in turn consumed by creatures higher in the food web. Fish, birds, and mammals tend to accumulate certain congeners over time in their fatty tissue. Concentrations of PCBs can reach levels hundreds of thousand times higher than the levels in water. Bioconcentration is the uptake of a chemical from water alone, while bioaccumulation is the result of combined uptake via food, sediment, and water. These processes can lead to high levels in the fat of predatory animals.[25] Also, PCBs can biomagnify in fresh and saltwater ecosystems. Humans may be exposed to detectable quantities of PCBs when they eat fish, use fish oils in cooking, or consume meat, milk, or cheese; the half life of PCBs in humans is estimated to be 2 – 6 years.[26]

Toxicity

Toxic responses to PCBs include dermal toxicity, immunotoxicity, carcinogenicity, and adverse effects on reproduction, development, and endocrine functions. Several epidemiological studies indicate that consumption of background levels of PCBs may cause slight but measurable impairments in physical growth and learning behavior in children while others have not. Some PCB congeners have a structure and biological activity that is similar to dioxin.

EPA has determined that PCBs are probable human carcinogens and assigned them the cancer weight-of-evidence classification B2 based on animal studies. Human studies are being updated; current available evidence is inadequate but suggestive regarding cancer to humans. The upper-bound cancer slope factor for PCBs is 2.0 $(mg/kg/day)^{-1}$.

Part of the uncertainty in assessing PCB effects from consuming fish is that PCB congeners selectively bioaccumulate in fish in different patterns than found in commercial mixtures of PCBs or in the environment.[27] Another issue is how to combine cancer risks computed using PCB cancer potency factors based on Aroclors with cancer risks computed using TEFs for dioxin-like PCBs. The congener mix encountered by a fetus during pregnancy and nursing may be quite different than congener patterns initially released into the environment. Since PCB congeners differ in their potency and in the specific ways they interact with biological systems, health criteria based on data from Aroclor mixtures fed to animals (e.g., the EPA RfD) may not account for biodegradation or selective accumulation by an organism. EPA has addressed this uncertainty by a policy decision to use an upper bound, health-protective estimate of the PCB cancer potency factor when computing cancer risks for PCBs found in fish tissue.[28, 29]

DOH recently conducted a thorough review of the scientific literature on PCB toxicity in an attempt to set a state standard for PCB exposure through consumption of fish and shellfish. DOH concluded that ATSDR's MRL of 0.02 ug/kg/day for chronic-duration oral exposure to PCBs would be protective of the most sensitive population (fetus) for the

most sensitive endpoints reviewed (immune and developmental). The intermediate oral MRL is based on a lowest observed adverse effect level (LOAEL) of 0.005 mg/kg-day for immunological effects seen in adult monkeys' exposure to Aroclor 1254.[30] EPA verified an oral reference dose (RfD) of 0.02 ug/kg-day for Aroclor 1254,[31] based on dermal/ocular and immunological effects in monkeys.

Polybrominated diphenyl ethers (PBDEs)

A new area of concern for human health is the widespread environmental presence of polybrominated diphenyl ethers (PBDEs), which are flame retardants used in a variety of consumer and industrial products. Puget Sound Assessment and Monitoring Program (PSAMP) has begun collecting fish tissue data for this analyte.[32] PBDEs were recently identified as bioaccumulative in the environment and have been detected in a variety of human tissues and in other organisms. Given the long life of many PBDE products and the length of time they remain in the environment, exposure can continue for years after their production. Washington State has developed a draft chemical action plan to identify efforts the state may take to reduce threats posed by some PBDEs.[33]

PBDEs are chemicals added to plastics and fabrics to prevent them from catching on fire or burning when exposed to flame or high heat. Levels of PBDEs have increased rapidly in soil, air, and wildlife and have been detected in a variety of human tissues and in other organisms. The health impacts of PBDEs have not been studied in people. Information on the possible health effects of PBDEs comes from studies conducted in laboratory animals. These animal studies indicate that the developing fetus and infants are the most sensitive to the potential toxic effects of PBDEs. Some of the effects of PBDEs observed in animals include changes in brain development leading to altered behavior, learning and memory later in life. PBDE exposure is also associated with decreases in thyroid hormones and changes in the development of reproductive effects. Chemicals like PBDEs and PCBs are bioaccumulative, meaning they can stay in our bodies for a very long time.

Identifying sources of PBDE exposure in the general population continues to be an area of active research. Early studies indicate that food is likely the main source of exposure to PBDEs. Although structural similarities between PBDEs and PCBs suggest that food would likely be the main source of exposure to PBDEs since food is the primary source of human exposure to PCBs,[34, 35] recent studies indicate that indoor dust is the main source of exposure to PBDEs especially in children.[36, 35]

As mentioned before, information on possible health impacts of PBDEs comes primarily from animal toxicity studies.[37] In general, specific PBDE congeners found in penta-PBDE commercial products are more toxic than octa-PBDE and deca-PBDE. Deca-PBDE breaks down to penta-PBDE. The most sensitive toxic effect associated with penta-PBDE congeners appears to be developmental neurotoxicity, although penta-PBDE may also impact thyroid and other hormone systems. Octa-PBDE showed fetal toxicity and liver changes in rat and rabbit studies. Dietary intake of deca-PBDE was associated with liver, pancreas, and thyroid tumors at very high doses in rodent studies. Washington State's PBDE chemical action plan states that human health risks are associated with PBDE exposure, although pathways and levels that may result in harm are not clearly

understood. While consumption of food, including fish, may be an important exposure pathway for these chemicals, the indoor environment poses a unique exposure pathway for PBDEs unlike pathways for other persistent bioaccumulative toxins.

Five congeners (PBDE-47, -99, -100, -153, and -154) predominate in human tissues, usually accounting for more than 90% of the total PBDE body burden in most individuals not occupationally exposed. PBDE-47, -99, and -100 are present in the penta-BDE technical mixture, whereas PBDE-153 and -154 are constituents of both the penta-BDE and octa-BDE technical mixtures. Growing evidence suggests that the more highly brominated congeners of the deca-BDE technical mixture break down in the environment (e.g., lose bromine atoms through sunlight degradation and biotic metabolism) and subsequently form lower brominated PBDE congeners commonly found in humans.[38, 39]

Current PBDE toxicity values provided by EPA do not indicate the need to provide fish consumption advice based on this contaminant (RfDs = 7×10^{-3} mg/kg-day for decabromodiphenyl ether, 3×10^{-3} mg/kg-day for octabromodiphenyl ether, and 1×10^{-4} mg/kg-day for pentabromodiphenyl ether) (mg/kg = ppm). Unfortunately, toxicity data for PBDEs are limited. EPA's current critical toxicity values for PBDEs considers recent animal studies showing similar adverse neurodevelopmental effects as observed with mercury and PCBs. The U.S. EPA has conducted a peer review of the scientific basis supporting the human health hazard and dose-response assessments of four congeners of polybrominated diphenyl ethers: tetraBDE (BDE-47), pentaBDE (BDE-99), hexaBDE (BDE-153), and decaBDE (BDE-209). A comprehensive review of toxicity data is included in the Integrated Risk Information System (IRIS) database.[40] Based on recent research in animals (rats), EPA's new reference dose values are as follows:

- BDE-47 (tetrabromodiphenyl ether) reference dose (RfD) corresponds to 1×10^{-4} mg/kg-day or 0.1 ug/kg-day (critical effect, neurobehavioral effects).
- BDE-99 (pentabromodiphenyl ether) RfD corresponds to 1.0×10^{-4} mg/kg-day or 0.1 ug/kg-day (critical effect, neurobehavioral effects).
- BDE-153 (hexabromodiphenyl ether) RfD corresponds to 2×10^{-4} mg/kg-day or 0.2 ug/kg-day (critical effect, neurobehavioral effects).
- BDE-209 (decabromodiphenyl ether) RfD corresponds to 7×10^{-3} mg/kg-day or 7 ug/kg-day (critical effect, neurobehavioral effects).

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